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EFFECTS OF HYDROCOOLING ON THE DESSERT QUALITY AND STORAGE LIFE OF APPLES IN THE PACIFIC NORTHWEST

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SUMMARY

Three varieties of apples--Red Delicious, Golden Delicious, and Winesap--were cooled according to the following procedures: Hydrocooled to core temperature of 40° F.; hydrocooled to 40° 1/2 inch deep into flesh; air-cooled to 32° in 3 days, in 7 days, in 14 days, and in 28 days. The fruit was examined at intervals over a long storage period.

The hydrocooled fruit and the fruit that was air cooled in 3 days and 7 days were comparable in quality and storage life expectancy. Red Delicious fruit cooled over 14-day and 28-day intervals were inferior at all examinations, and became mealy and unfit for consumption. Golden Delicious apples from all six cooling procedures gradually lost their differences with extension of the storage season, so that after 7 months no significant differences were found. The Winesap apples that were slowly cooled softened more rapidly than the other lots but the softening was not sufficient to be objectionable to the taste panel.

The results indicate that hydrocooling would be beneficial for these three varieties of apples when they cannot be cooled to 32° F. within 7 days.

INTRODUCTION

In good commercial cold storages, apples are cooled to a core temperature of approximately 32° F. in 3 or 4 days. In many storages, however, such rapid cooling is not attained because these storages lack sufficient refrigeration capacity. This is especially true in years when the weather at harvesttime is warm and when the fruit is placed in the cold storage rooms faster than the refrigeration equipment can remove the heat from it. Several weeks are sometimes required to cool the apples to the desired storage temperature of 30°-31°. In these instances, hydrocooling would remove most of the field heat from the apples, after which the existing refrigeration equipment in the storages would be adequate for complete cooling and maintenance of the desired temperature. This study was made to determine the rate of air cooling at which hydrocooling first shows a measurable improvement in fruit quality during subsequent storage.

METHODS

Fruit

Three varieties of apples, Red Delicious (Starking), Golden Delicious, and Winesap, were used in the cooling tests. All were harvested from selected trees at the Tree Fruit Research Center, Wenatchee, Wash. The fruit was washed and sized using standard methods and equipment. Only sizes 100 and 113 apples were used in the cooling tests.

Red Delicious fruit of optimum maturity for long storage, picked at 145 days from full bloom, was used for one season's tests, while fruit of more advanced maturity (picked at 155 days from full bloom) was used in two seasons.

Golden Delicious, picked at 145, 155, and 165 days from full bloom in three different seasons, were used to determine whether the benefits of rapid cooling might be related to maturity of the fruit.

All the fruit of the two Delicious varieties were sorted by transmitted light (I.Q. sorter)[1] and the experimental fruit was selected from lots having the same light transmittance readings, and randomized to insure uniformity of lots.

The Winesap apples were harvested at 165 days from bloom and were randomized before cooling.

Each lot of fruit was held at room temperature for 24 hours before the cooling tests were started so that all the fruit would be at a uniform temperature at the start.

The Delicious and Winesap apples were jumble packed into standard wood apple boxes, and a thermocouple was inserted into a fruit near the center of each pack. The Golden Delicious apples were tray packed in fiberboard boxes with polyethylene liners to protect them from shrivel during storage. However, the hydrocooling was done in wood boxes, the apples then being repacked immediately into fiberboard boxes.

Cooling Procedures

Six different cooling procedures were used in the tests.

1. Hydrocooled to a core temperature of 40° F., then placed in storage at 30°-31°.
2. Hydrocooled to 40° at a depth of 1/2 inch in the apple, then placed in storage at 30°-31°.
3. Air-cooled with the temperature controlled so that the core temperature reached 35° in 3 days and then held at 30°-31°. (This cooling rate was obtained by placing the boxes of fruit immediately after packing into a storage room held at 30°-31°.)
4. Air-cooled in refrigerated chambers at a rate which lowered the core temperature to 35° in 7 days. The fruit was then placed in storage at 30°-31°.
5. Same as 4, except the cooling rate was slower, the core temperature reaching 35° in 14 days.
6. Same as 4, except the core temperature of 35° was reached in 28 days.

For hydrocooling, a steel tank was partly filled with 200 gallons of water to which 500 pounds of crushed ice was added. The water was agitated with an electrically operated stirrer. Duplicate boxes of each lot to be hydrocooled were submerged into the ice water, removed when the temperature of the fruit reached 40° F., drained, and placed immediately in 30°-31° storage.

Quality Evaluation

Samples of each experimental lot of fruit were examined at intervals during storage. Each sample consisted of 20 apples, on which flesh firmness, soluble solids, titratable acids, and organoleptic evaluations were made. Flesh firmness was determined with the Magness-Taylor tester, soluble solids in the juice with a hand refractometer, and acidity of the juice with glass electrode titrimeter. The organoleptic analyses were made on the five apples whose flesh firmness was closest to the mean for the entire sample. Slices from each of the five apples were evaluated for texture and flavor by the taste panel.

RESULTS

Hydrocooled apples did not have better quality or a longer storage life than apples air-cooled to the same temperature within 7 days. The quality evaluations for the three varieties used are summarized in tables 1-3.

Red Delicious

The two hydrocooled lots and the 3- and 7-day air-cooled lots were very similar in firmness, soluble solids content, acidity and dessert quality ratings. The small differences shown might be expected as sample variation.

The fruit that was cooled over the 14- and 28-day periods softened rapidly and was inferior to the other lots at all examinations. The 155-day fruit became mealy and the 28-day lot was discarded in March. Soluble solids were generally a little higher in the 28-day

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[1] Yeatman, John N. and Karl H. Norris. Evaluating Internal Quality of Apples with New Automatic Fruit Sorter. Food Technol. 19(3): 123-125, 1965.

Table 1.--Quality evaluations of Starking Delicious apples, harvested 145 and 155 days from full bloom, cooled at various rates after harvest and stored at 31° F.

Cooling procedure	Flesh firmness					Soluble solids					Titratable acids					Taste panel ratings[1]				
	Nov.	Jan.	Mar.	May	June	Nov.	Jan.	Mar.	May	June	Nov.	Jan.	Mar.	May	June	Nov.	Jan.	Mar.	May	June
145 Days From Bloom																				
	Lb.	Lb.	Lb.	Lb.	Lb.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.					
Hydrocooled:																				
Core	--	13.9	12.9	12.8	--	--	13.6	13.4	13.1	--	--	0.197	0.168	0.135	--	--	61.2	61.2	52.8	--
1/2 inch in flesh	--	13.4	13.1	13.0	--	--	13.7	13.6	13.0	--	--	.195	.174	.133	--	--	63.3	55.8	52.3	--
Air-cooled:																				
3 days	--	13.5	13.1	12.9	--	--	13.3	13.6	13.1	--	--	.218	.161	.134	--	--	69.5	62.7	56.8	--
7 days	--	13.4	12.6	12.3	--	--	13.6	13.5	13.7	--	--	.205	.172	.120	--	--	65.0	59.7	54.5	--
14 days	--	13.3	12.3	10.6	--	--	13.6	13.5	13.0	--	--	.222	.181	.137	--	--	60.3	50.3	46.3	--
28 days	---	10.5	10.3	10.1	--	--	13.9	14.0	13.5	--	--	.220	.186	.167	--	--	32.5	32.7	30.7	--
155 Days From Bloom																				
Hydrocooled:																				
Core	16.2	14.0	13.2	12.3	12.2	13.9	14.1	13.6	13.4	13.9	0.226	.191	.150	.134	0.099	78.0	67.9	59.8	59.7	59.7
1/2 inch in flesh	15.8	14.0	12.9	12.4	11.9	13.6	13.1	13.3	13.1	13.8	.237	.188	.154	.134	.115	78.9	67.9	62.6	52.5	60.6
Air-cooled:																				
3 days	16.9	14.2	13.6	12.7	12.6	14.0	13.3	13.3	13.0	14.0	.226	.191	.165	.128	.099	80.0	69.2	63.3	59.8	60.8
7 days	16.0	14.1	13.3	12.1	12.5	14.4	13.4	13.4	12.9	13.9	.226	.198	.155	.134	.122	89.9	69.5	64.0	54.2	63.0
14 days	13.3	11.7	11.5	10.4	10.4	14.0	13.6	13.2	13.0	13.4	.234	.196	.174	.136	.135	71.5	59.6	57.9	47.6	52.5
28 days	10.4	9.8	10.5	9.6	8.7	14.8	14.3	14.8	13.2	13.4	.226	.204	.177	.157	.158	47.5	39.9	26.0	--	--

[1] Excellent = 81-100; good = 66-80; fair = 46-65; poor = 26-45.

Table 2.--Quality evaluations of Golden Delicious apples, harvested 145, 155, and 165 days from full bloom, cooled at various rates after harvest and stored at 31° F.

Cooling procedure	Flesh firmness				Soluble solids				Titratable acid				Taste panel ratings[1]			
	Nov.	Jan.	Mar.	May	Nov.	Jan.	Mar.	May	Nov.	Jan.	Mar.	May	Nov.	Jan.	Mar.	May
145 Days From Bloom																
	Lb.	Lb.	Lb.	Lb.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.				
Hydrocooled:																
Core	--	11.0	10.7	10.0	--	13.9	13.4	13.5	--	0.303	0.245	0.174	--	62.5	56.3	47.7
1/2 inch in flesh	--	11.3	11.0	10.3	--	14.0	13.6	13.4	--	.307	.245	.169	--	63.5	53.7	49.5
Room-cooled:																
3 days	--	11.1	11.0	10.4	--	13.8	13.6	13.3	--	.301	.250	.162	--	62.8	52.0	51.3
7 days	--	11.0	10.7	10.2	--	14.0	13.7	13.3	--	.332	.251	.159	--	68.1	55.5	47.5
14 days	--	10.4	10.3	10.1	--	14.0	13.8	13.7	--	.289	.245	.180	--	51.6	48.0	41.2
28 days	--	10.6	10.3	9.7	--	14.0	14.1	13.5	--	.282	.236	.181	--	44.8	45.8	44.7
155 Days From Bloom																
Hydrocooled:																
Core	16.2	11.7	10.9	10.7	13.2	12.9	12.8	12.6	0.322	.322	.211	.181	81.3	61.5	56.5	59.3
1/2 inch in flesh	15.9	11.4	10.8	10.6	12.9	13.0	13.1	12.2	.358	.301	.230	.189	79.5	71.0	60.8	57.5
Air-cooled:																
3 days	15.6	11.6	10.3	10.3	13.4	13.0	12.9	12.6	.363	.329	.224	.187	81.9	55.5	55.8	55.5
7 days	15.8	10.9	10.1	9.9	13.1	13.1	13.1	12.7	.326	.276	.203	.209	74.3	63.2	52.7	53.6
14 days	15.5	10.6	9.5	9.6	12.7	12.9	13.0	12.5	.297	.238	.187	.206	76.7	57.0	51.7	48.2
28 days	11.6	9.9	9.3	9.0	13.0	12.7	13.0	12.4	.268	.228	.164	.121	63.7	45.3	46.8	45.0
165 Days From Bloom																
Hydrocooled:																
1/2 inch in flesh	--	11.2	9.8	9.3	--	12.9	12.9	12.7	--	.277	.178	.115	--	57.3	52.0	43.7
Air-cooled:																
3 days	--	11.5	10.6	9.8	--	13.1	12.9	13.5	--	.254	.185	.135	--	63.0	51.0	46.3
7 days	--	10.7	9.5	9.6	--	12.9	13.0	12.7	--	.234	.181	.120	--	60.0	51.4	40.3
14 days	--	10.5	9.7	9.5	--	13.1	12.7	12.4	--	.253	.164	.110	--	56.7	52.4	42.0

[1] Ratings were as follows: Excellent = 81-100; good = 66-80; fair = 46-55; poor = 26-45.

Table 3.--Quality evaluations of Winesap apples, harvested 160 and 165 days from full bloom, cooled at various rates and stored at 31° F.

Cooling procedure	Flesh firmness						Soluble solids					
	Nov.	Jan.	Mar.	Apr.	June	Aug.	Nov.	Jan.	Mar.	Apr.	June	Aug.
165 Days From Bloom												
Hydrocooled:	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Core................	20.4	19.5	18.0	--	15.8	15.3	13.1	13.0	13.5	--	13.0	13.4
1/2 inch in flesh...	20.9	19.7	17.2	--	16.1	15.1	12.7	12.9	13.6	--	13.1	13.6
Air-cooled:												
3 days..............	20.6	19.8	18.0	--	15.9	15.4	12.9	13.2	13.6	--	13.1	13.1
7 days..............	20.3	18.6	18.1	--	15.5	15.1	12.9	13.0	13.6	--	13.0	13.4
14 days.............	20.1	18.1	16.7	--	14.9	15.0	13.0	13.1	13.7	--	13.0	13.1
28 days.............	17.8	16.3	15.6	--	14.7	13.8	13.4	13.5	13.7	--	13.1	13.1
160 Days From Bloom												
Hydrocooled:												
Core................	--	--	--	16.7	15.0	15.0	--	--	--	15.2	15.1	15.0
1/2 inch in flesh...	--	--	--	16.4	15.0	14.6	--	--	--	15.2	15.4	15.1
Air-cooled:												
3 days..............	--	--	--	16.4	14.8	14.5	--	--	--	15.0	14.9	15.3
7 days..............	--	--	--	16.1	14.6	14.9	--	--	--	15.0	14.8	15.1
14 days.............	--	--	--	15.9	14.4	14.5	--	--	--	14.9	15.1	15.1
28 days.............	--	--	--	15.4	13.8	13.3	--	--	--	15.1	15.1	14.6

Cooling procedure	Titratable acids						Taste panel ratings[1]					
	Nov.	Jan.	Mar.	Apr.	June	Aug.	Nov.	Jan.	Mar.	Apr.	June	Aug.
165 Days From Bloom												
Hydrocooled:	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.						
Core................	0.669	0.623	0.599	--	0.541	0.488	65.5	67.9	71.6	--	72.4	59.2
1/2 inch in flesh...	.728	.615	.589	--	.541	.486	64.2	67.8	63.1	--	71.4	65.4
Air-cooled:												
3 days..............	.667	.631	.591	--	.536	.473	63.3	66.1	68.0	--	71.0	60.7
7 days..............	.647	.643	.578	--	.546	.520	66.1	68.6	64.2	--	71.6	67.1
14 days.............	.656	.633	.623	--	.548	.503	65.8	68.0	66.2	--	68.0	63.3
28 days.............	.621	.593	.599	--	.542	.546	63.8	69.0	69.4	--	71.6	59.3
160 Days From Bloom												
Hydrocooled:												
Core................	--	--	--	.638	.564	.526	--	--	--	65.7	58.5	53.4
1/2 inch in fleshs..	--	--	--	.595	.602	.513	--	--	--	70.7	54.3	55.8
Air-cooled:												
3 days..............	--	--	--	.658	.589	.504	--	--	--	68.7	55.2	56.6
7 days..............	--	--	--	.651	.584	.522	--	--	--	65.7	56.7	56.2
14 days.............	--	--	--	.638	.564	.537	--	--	--	58.2	54.8	48.2
28 days.............	--	--	--	.647	.569	.564	--	--	--	62.5	51.5	48.8

[1] Ratings were as follows: Excellent = 81-100; good = 66-80; fair = 46-55; poor = 26-45.

lot--a characteristic of overripe apples. The acid content of the slowly cooled lots was also somewhat higher than that of the other fruit.

Golden Delicious

This variety softens more rapidly during early storage than Red Delicious after which the softening rate slows down and remains slow during the rest of the storage period (table 2). The fruit that required 4 weeks to cool had softened to 11.6 pounds in November, the range in flesh firmness at that time being from 11.6 to 16.2 pounds (table 2, 155-day fruit). By January the fruit in all lots was from firm ripe to ripe (11.7 to 9.9 lbs.) and there was not much difference between lots.

The dessert quality of Goldens that were cooled at favorable rates was judged by the taste panel to be from excellent to good in November and good to fair in January, after which the quality declined slowly. The differences in dessert quality between the rapidly cooled and slowly cooled lots also became less with the advance of the storage season, so that by May there were no marked differences among any of the lots. Fruit of the three maturities reacted similarly.

Winesap

There was little difference among the various lots of this long-storage variety (table 3). The fruit that cooled gradually over a 28-day period softened during that period more than any of the other lots, and remained softer during the entire storage period. However, the softening was not sufficient to cause mealiness nor to make the fruit objectionable to the taste panel.

Effect on Disorders of Red Delicious

The 8-month storage period plus 5 days at 70° was a severe test for resistance of the apples to storage scald, breakdown, and decay. The results are summarized in table 4.

Storage scald incidence was highest on the hydrocooled and 3-day lots and lowest on the 7-day lots in both 145- and 155-day fruit. No scald inhibitors or oiled wraps were used to control the disorder.

Table 4.--Percentages of storage disorders on Red Delicious apples, picked at 145 and 155 days from bloom, and stored at 31° F. for 8 months, plus 5 days at 70°

Days from bloom at harvest	Cooling treatment				
	Hydro-cooled	Air-cooled			
		3 days	7 days	14 days	28 days
	Pct.	Pct.	Pct.	Pct.	Pct.
	Storage Scald				
145.......	67.8	77.0	51.5	68.0	52.0
155.......	18.5	17.8	7.6	10.0	10.2
	Breakdown				
145.......	.7	2.0	0	0	0
155.......	3.0	5.6	8.5	5.1	20.8
	Decay				
145.......	4.7	2.1	3.0	2.0	2.0
155.......	7.6	2.0	2.5	2.5	2.0

Breakdown increased with fruit maturity, the occurrence being very low in the 145-day fruit, and severe in the 155-day fruit, especially the lot cooled in 28 days.

Decay incidence was highest in the hydrocooled lots due principally to core rot. Open calyxes were occasionally observed, and the core rot was undoubtedly due to water and inoculum which entered these openings.

Decay was more prevalent in Golden Delicious than in Red Delicious and was very serious in the slowly cooled lots. The percentages of decaying Golden Delicious fruits at the final examination averaged 7.8, 7.3, 8.4, 23.8 and 40.7 for the hydrocooled and 3, 7, 14 and 28-day air-cooled lots, respectively. No open lenticels were observed in the Golden Delicious fruits.

DISCUSSION

Hydrocooling has been used for many years for rapidly cooling very perishable vegetables and for some fruits, especially peaches grown in the Southern States. It has not been used extensively for precooling long-keeping fruits, such as apples or pears. Blanpied[2] reported an easily discernible difference for the first 3 months in lots of McIntosh apples that were hydrocooled or air-cooled in 3 days, and 1, 2, or 3 weeks. As the storage period increased, it became increasingly difficult to separate the treatments, until after 4 and 5 months the hydrocooled, 3-day cooled, and 7-day cooled apples were judged to be about equal.

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[2] Blanpied, G. D. The effect of cooling rate on the market quality of McIntosh apples. Amer. Soc. Hort. Sci. Proc. 70: 58-66. 1957.

Similar results with Golden Delicious were found in the tests reported here. After 1 month of storage (November), the flesh firmness was about the same for the hydrocooled and 3-, 7-, and 14-day air-cooled lots, and no difference in dessert quality was found between the hydrocooled and 3-day lots. After 3 months in storage, no significant differences were found in the hydrocooled and the 3- and 7-day air-cooled lots, while the 14- and 28-day air-cooled lots were generally inferior in quality. The differences were even less at the final examination after 7 months of storage. The rate of decline in quality was somewhat greater in the fruit picked 165 days from bloom than in the less mature fruit.

The Red Delicious lots that were hydrocooled and air-cooled in 3 and 7 days did not show consistent differences at any of the evaluation periods in storage. The fruit that was more slowly cooled, 14-day and 28-day periods, was inferior at all examinations, having become mealy, a characteristic not occurring in Golden Delicious.

Winesap apples that were slowly cooled were preferred by some members of the taste panel, indicating that quality in this long-storage variety may improve with a considerable amount of ripening. There was little difference in preference by the taste panel during any of the examinations, even after 10 month's storage.

These studies indicate that for long storage of apples, hydrocooling offers no advantages over air-cooling in cold storage rooms, providing the cooling to approximately 32° F. is accomplished within a week. If there is insufficient refrigeration capacity in a warehouse and a number of storage units are involved, hydrocooling might be advisable.

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